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# Performance Evaluation of Roadway Subdrain Outlets in Iowa

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# Performance Evaluation of Roadway Subdrain Outlets in Iowa

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and Robert F. Steffes

The bearing capacity and service life of a pavement are adversely affected by the presence of undrained water in the pavement layers. In cold winter climates, such as in Iowa, this problem is magnified further by the risk of frost damage when water is present. Therefore, well-performing subsurface drainage systems form an important aspect of pavement design by the Iowa Department of Transportation (DOT). However, there was a need to determine the impacts of not maintaining the subdrain outlets on pavement performance in Iowa in light of the recent Iowa DOT field maintenance staff reductions and budget cuts and the implications on subdrain outlet maintenance. Consequently, a research study was initiated to conduct a performance review of primary interstate pavement subdrains in Iowa and determine the cause of the problem if there were drains that were not functioning properly. Field investigations were conducted on 64 selected (jointed plain concrete pavement and hot-mix asphalt) pavement sites during the 2012 fall season. The study was mainly focused on the drainage outlet conditions. Findings and observations based on an extensive literature review and forensic testing are discussed in this paper. Gate and mesh screen-type rodent guards are not recommended for Iowa subdrainage systems because they tend to catalyze outlet blockage and end up potentially doing more harm (i.e., requiring more frequent maintenance) than good (i.e., protection against rodent intrusion).

The detrimental effects of water in pavement structures are known to cause and accelerate distresses in portland cement concrete (PCC) and hot-mix asphalt (HMA) pavements. The presence of subsurface drainage systems is generally believed to be beneficial to the performance of both PCC and HMA pavements. Iowa subgrade soils, in general, are fine grained and have low permeability and poor drainage quality by AASHTO standards: less than 10 ft per day ( $<5$  in./h). Iowa also receives more than 20 in. of precipitation in a year and is considered a wet climate. Considering all this, lack of subsurface drainage systems in Iowa pavements can lead to potential saturation of subgrades and subbases for long periods of time (1).

Previous studies have reported that properly designed, constructed, and maintained pavements that incorporate positive subsurface drainage features can greatly extend the life of a pavement. However, controversial findings are also reported in the literature (2–6) about the

benefits of subsurface drainage. For instance, Hassan et al., reporting on Indiana Department of Transportation's (DOT) subdrainage experience, concluded that "an improperly designed, constructed, or maintained subdrainage system can cause more problems than it solves" (2). Similarly, the *Mechanistic–Empirical Pavement Design Guide* (MEPDG) developed through the NCHRP Project 1-37A (5), which has now evolved into AASHTOWare Pavement ME Design, states that "the current state of the art is such that conclusive remarks regarding the effectiveness of pavement subsurface drainage or the need for subsurface drainage are not possible."

In addition, the use of recycled portland cement concrete (RPCC) or recycled concrete aggregate (RCA) as a granular subbase is a prevalent pavement construction practice by the Iowa DOT. A previous study by Steffes showed that excessive fines in RPCC can cause calcification deposits, more commonly known as tufa, to form on the subdrain rodent guards, blocking the outlet (7). Although Iowa DOT's RPCC material specifications were revised following this study to reduce the formation of these deposits and subsequent blockage, no follow-up studies have been conducted to verify the effectiveness of the revised specifications.

In light of the recent Iowa DOT field maintenance staff reductions and budget cuts and the associated implications on subdrain outlet maintenance, there was a need to determine the impacts of not maintaining the subdrain outlets on pavement performance in Iowa. The goal was also to determine if there are pavements in Iowa exhibiting moisture-related distress or failure that can be attributed to poor subdrain performance and to investigate whether the poor subdrain performance is caused by improper design, construction, or maintenance. As a first step, a forensic testing and evaluation study was undertaken to review the field performance of primary interstate pavement subdrains in Iowa and to determine the cause of the problem if there were drains that were not functioning properly.

## OBJECTIVES AND SCOPE

The specific objectives of this study were to (a) conduct an extensive performance review of primary interstate pavement subdrains in Iowa, (b) include the condition of the drains and a determination of whether they were functioning as designed, (c) evaluate a corresponding pavement to determine if pavement deterioration was occurring at the drain locations, (d) determine the cause of the problem if there were drains that were not functioning properly, and (e) make recommendations for improvements to the pavement drainage system, when appropriate. It is important to note that this research study was not intended to investigate whether or not Iowa pavements need subdrains, but to evaluate the subsurface drainage practices in Iowa.

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First, an extensive literature review was performed covering national-level and state-level research studies mainly focusing on the effects of subsurface drainage on performance of concrete and asphalt pavements. Several studies concerning the effects of RCA or RPCC subbase on PCC pavement drainage systems were also reviewed. Second, a detailed forensic test plan was developed in consultation with the Iowa DOT engineers for inspecting and evaluating the Iowa pavement subdrains. Field performance investigations were then conducted on 64 selected [jointed plain concrete pavement (JPCP) and HMA] pavement sites during the fall season of 2012 and were mainly focused on the drainage outlet conditions.

## LITERATURE REVIEW

A comprehensive literature review was performed covering national-level and state-level research studies. Ceylan et al. summarized the subsurface drainage investigation procedures and findings reported by these studies (8). A discussion of significant findings relevant to this study is presented in the following subsections.

### National-Level Research Studies

This section mainly focuses on a review of the NCHRP 1-34X projects that were carried out between 1998 and 2007. The NCHRP Project 1-34, Performance of Subsurface Pavement Drainage, was one of the first and extensive national-level studies undertaken to evaluate the overall effect of subsurface drainage of surface infiltration water on the performance of flexible (HMA) and rigid (PCC) pavements, as well as the specific effectiveness of permeable base and associated edge drains, traditional dense-graded bases with and without edge drains, and retrofitted surface drainage on existing pavements (9). Based on an extensive body of field data obtained through 1998, the following key questions were addressed through this research: (a) do the various subsurface drainage design features contribute to improved flexible and rigid pavement performance?; and (b) are the subsurface drainage design features cost-effective and under what conditions?

On the basis of the previous studies on the impact of subsurface drainage, performance comparisons between drained and non-drained experimental sections included in NCHRP Project 1-34, and distress predictions from mechanistic–empirical models, several findings were drawn. A significant finding from this study was that the benefits of subsurface drainage must be considered along with the potential of design-, construction-, or maintenance-related problems associated with it. The positive effect of the drainage feature may become negated if the subsurface drainage system fails to function properly over the pavement service life (3).

The findings of NCHRP Project 1-34 were limited by a number of conditions, including small sample size, the young age of the majority of the test sections considered in the analysis, and the lack of data and resources on the functional condition of the subsurface drainage systems. To evaluate the unexpected findings reported by NCHRP Project 1-34 further, the NCHRP panel established subsequent projects 1-34B, 1-34C, and 1-34D.

Under NCHRP Project 1-34C, a detailed plan was developed to quantify the effects of subsurface drainage on pavement performance on the basis of statistical analyses of Long-Term Pavement Performance (LTPP) Specific Pavement Study 1 (SPS-1) and Specific Pavement Study 2 (SPS-2) data, and the extensive results

and findings were published as NCHRP Report 499 (4). Apart from the data from the LTPP SPS-1 and SPS-2 experiments, the findings from the video inspection of edge drains at the SPS-1 and SPS-2 sites conducted during the course of the project to determine their functionality were also included in the analysis.

In an effort to better define the effect of subsurface drainage on pavement performance following Project 1-34C, the NCHRP Project 1-34D was undertaken with the following specific objectives: to quantitatively test the functionality of the subsurface drainage features in the LTPP SPS-1 and SPS-2 pavement sections and to refine the relationships between subsurface drainage and pavement performance that were developed originally through Projects 1-34 and 1-34C. The final report documenting the entire research effort was published as NCHRP Report 583 (6).

The NCHRP Project 1-34D made use of the more recent performance data from LTPP Data Release 19.0 (January 2005), analysis of falling weight deflectometer deflection data to assess the relative structural contributions of different base types, and subdrainage system flow time measurements to assess how well the subsurface drainage systems function. In addition, data from the Minnesota Road (MnRoad) Research Project and Wisconsin DOT drainage studies were included in the analysis. Further, regression analysis was employed to address the larger question of how much does the base and subbase drainage factor of the SPS-1 and SPS-2 experimental designs influence pavement performance (roughness) compared with other experimental factors and site features?

The overall conclusion from NCHRP Project 1-34D seemed to indicate that the presence of subsurface pavement drainage did not improve the performance of HMA (LTPP SPS-1) and PCC (LTPP SPS-2) pavement structures. It is not the drainability of the base layers, but the stiffness, which, according to the authors (6), influenced deflection response, roughness, rutting, faulting, and cracking. However, the authors do recommend considering the need for a subsurface drainage system at sites with wet climates and poorly draining soils, particularly for pavement designs that are more vulnerable to moisture-related distress, such as thin asphalt and thin concrete pavements on untreated aggregate base layers (6).

### State-Level Research Studies

Hassan et al. covered the most recent applications of pavement subdrainage in Indiana (2). They focused primarily on summarizing two previous research studies (10, 11) as well as ongoing long-term research efforts to address issues related to use of subdrainage in Indiana, especially the question of the optimum location and combination of base layers. On the basis of these research efforts, several modifications to Indiana DOT subsurface drainage policy were implemented, including the implementation of a routine subdrain inspection and maintenance program and a proposal to replace precast concrete outlet protectors with larger cast or in-place concrete pads or pillows to help locate the outlet pipes more easily and to prevent vegetation from growing up around the outlets.

In Minnesota, Canelon and Nieber evaluated both edge drains and centerline drains at various depths (2 and 4 ft) to determine if centerline drainage systems are an effective alternative to edge drains (12). Select draining sections were also inspected for calcification deposits (tufa) in an effort to determine the extent to which the material leaching through recycled concrete aggregate calcifies and obstructs the flow into the drain. On the basis of data collected over a 2-year period, statistical analysis, and finite element



analysis of the drainage configurations, a number of observations were made. Contrary to expectations, drainage lines that showed high levels of carbonate deposits were not in sections with recycled concrete aggregates. The researchers did not provide further insight into this except to state that carbonate sands in those locations may have led to this observation. There was no strong evidence between moisture readings (measured using an electromagnetic instrument) and pavement distress.

In conjunction with the study carried out by Canelon and Nieber (12), a subsurface drainage manual for Minnesota pavements was also developed, taking into account the variability of the soils, hydrology, and climate of the state (13). The manual includes methods for evaluating the need for subsurface drainage in Minnesota pavements, the selection of the type and design of the drainage system, guidelines on the construction and installation of subsurface drainage, proper maintenance of a drainage system, and methods for conducting an economic analysis of subsurface drainage.

Bhattacharya et al. discussed a recently completed study by the California Department of Transportation (Caltrans) to evaluate the performance of edge drain systems placed along PCC pavements in California and made recommendations to improve their performance (14). Over the years, a wide range of subsurface drainage designs have been constructed in California from retrofit drains to full subdrainage systems. However, it was later found that many of these drainage systems became ineffective because of design deficiencies, materials used, construction errors, and especially lack of maintenance. A total of 24 projects in 15 counties were surveyed and nine were selected for further evaluation by excavating the shoulder. Field investigations revealed that fewer than 30% of the evaluated edge drains, which were generally in the areas of higher rainfall, were operating in an acceptable manner. The majority of the remaining sites revealed little or no maintenance and the drain pipes were clogged with soil from both roadbed drainage and the shoulder area. The lack of end wall protection further exacerbated the clogging of outlet pipes. However, in many of the pavement sections, no significant correlation was found between observed pavement distresses and clogged edge drains, probably because of recent pavement rehabilitation activities by Bhattacharya et al. (14).

### Effect of RPCC Base and Subbase on Concrete Pavement Drainage

The use of RPCC, RCA, and crushed concrete (often used interchangeably although they have specific definitions with respect to the source) as replacements for virgin aggregates in the unbound base and subbase layers of concrete pavements has been a common practice in the United States for many years (15). However, field investigations carried out by different state highway agencies have raised concerns on the deposit of RPCC-associated fines and precipitate and their role in reducing the capacity of subsurface drainage systems. Snyder and Bruinsma reviewed several published as well as unpublished field studies concerning the effects of RPCC bases on PCC pavement drainage (16).

In Iowa, RPCC has been used in concrete pavement subbase for about 30 years. Previous field investigations revealed that this led to the formation of tufa blocking subdrains, reducing the subbase permeability, damaging the vegetation nearby the drain outlets, and sometimes causing pavement shoulders to erode (7, 17, 18). A survey conducted by Gupta and Kneller on the Ohio DOT use

of slag and RCA as subbase aggregates and related tufa problems revealed that not all RPCC subbase aggregates produced tufa and it was not clear why tufa precipitation did not occur on all sites using an RPCC subbase (19). In addition, previous studies indicate that calcite precipitates do not form with the use of natural aggregates such as gravel and crushed limestone, but with the use of RCA in the base and subbase (7, 18).

Several studies in the past have focused on investigating the conditions favorable for tufa formation when using RPCC, slags, or both in concrete pavement subbases, especially considering free lime as a chemical component to produce tufa. A study by Narita et al. suggested that slags containing more than 1% free lime were likely to produce tufa (20). Another study by Gupta and Dollimore led to the recommendation that the use of RPCC should be limited to coarse sizes to prevent the formation of tufa and that the RPCC used in base and subbase layers should have a magnesium-to-calcium ratio lower than 0.6 (21). Bruinsma et al. reported the residence time of pore water in RPCC subbase layers to be critical in controlling the tufa precipitate formation (22). Previous study findings suggest that tufa deposits are produced primarily from reactions between calcium hydroxide and other calcium-based compounds in portland cement paste of RCA, and carbon dioxide dissolved in water (18).

On the basis of an extensive review of several field studies conducted in Minnesota, Michigan, and Ohio concerning the effects of RPCC on PCC pavement drainage systems, Snyder and Bruinsma reported the following findings and recommendations (16):

- The use of RPCC in PCC base and subbase, irrespective of gradation, produces precipitate. The amount of precipitate appears to be related directly to the quantity of RPCC fines (#4-minus).
- Although selective grading (to eliminate fines) or blending with virgin aggregates will reduce the precipitation potential significantly, it will not eliminate it completely.
- The potential for accumulation of fine material deposits in and around pavement drainage systems can be reduced by washing the RPCC before using it in pavement foundation layers.
- The permittivity of typical drainage filter fabrics is reduced significantly by precipitate and insoluble residue accumulations resulting from the use of RPCC.
- To prevent corrosion of rodent guard screens from the use of RPCC, they should be fabricated from plastic or other corrosion-resistant materials.
- The use of the calcium ion concentration test (recommended by the Michigan DOT) may be a good test to determine the precipitate potential of RPCC products.
- The use of larger-diameter drainpipes that are either unwrapped or wrapped in filter fabrics with high initial permittivity is recommended.

## FORENSIC TESTING

### Site Selection

Pavement sites for forensic testing and evaluation were selected in consultation with the Iowa DOT engineers representing a variety of geographical locations, different pavement thicknesses, ranges of age and traffic, typical JPCP base and subbase layer composition (RPCC and virgin aggregate), ranges of pavement distress severities, and only JPCPs and HMA pavements designed and constructed after 1990 (i.e., the Iowa DOT was interested in actionable research

outcomes for the Office of Design that could be implemented today and therefore was not interested in investigating pavement and subdrain systems constructed before 1990). Fifty-six sites for new JPCP and eight sites for new full-depth HMA pavements were selected. The PCC surface thickness of the selected JPCPs ranged from 9 to 13 in. and granular base thickness ranged from 4 to 13 in. The HMA layer thickness of selected full-depth HMA pavements ranged from 9 to 15 in. The reason why JPCPs significantly outweighed HMA pavements in the site selection is that HMA pavements constitute only about 5% of the Iowa primary interstate pavement systems, while the rest (about 95%) are comprised of composite pavements and JPCPs. Also, Iowa DOT was more interested in including a number of problematic JPCP sites with blocked drain outlets presumably resulting from the use of RPCC subbase layer.

Among the selected Iowa pavement sites, higher average annual daily truck traffic (AADTT) was associated with JPCPs than with HMA pavements, in general. The age of selected JPCPs ranged from 10 to 20 years, while the HMA pavements were about 5 to 10 years of age. About 80% of the selected JPCP sites utilized RPCC as base materials, 15% utilized virgin aggregate, and the other 5% used blended RPCC and virgin aggregate as base materials. The base material properties requirements for use in Iowa roadways are described in Iowa DOT standard specifications (23) and *State-wide Urban Design and Specifications (1)*. Detailed descriptions of selected pavement sites can be found in Ceylan et al. (8).

### Field Investigation Methodology

Field investigations were conducted on 64 selected (JPCP and HMA) pavement sites during the fall season (October to November) of 2012. It is important to note that 2012 happened to be a drought year for Iowa and the precipitation during October and November 2012 ranged between 1 and 3 in.

Given that the drainage outlet visibly manifests the functionality of the entire drainage system and is related to most subdrainage problems, field investigations were focused on assessment of outlet condition. At least three drainage outlet spots per selected site (representing start, middle, and end of section) were investigated. The consideration for selection of each spot was based on vegetation condition near the drainage outlet, pavement distress condition, and ease of access to the outlet spot (without traffic control). Note that poor vegetation condition surrounding the drain outlet was considered as evidence of poor drainage performance. On the basis of the recommendations from the Iowa DOT and district maintenance engineers on problematic drainage sites, investigations were carried out every mile on some sites, such as I-80 in Cedar County and US-151 in Jones County. A total of 371 spots were investigated with respect to the selected JPCP and HMA pavement sites.

Most of the inspection took place on the right side of the roadway. The survey crew traveled in a car or a minitruck with a beacon light and stopped on the shoulder when needed for drainage inspection and the corresponding visual distress survey of pavements. At some spots, the outlets were covered by dirt, debris, soil, and other vegetation that had to be cleaned out by using hand tools for inspection. A template drainage inspection report, incorporating the following items, was prepared and used during field inspections:

- Location of outlet spot inspected,
- Types and size of outlet pipe,
- Condition of outlet opening,

- Screen present and type,
- Outlet maker present,
- Water present and condition (staying or moving) inside drain,
- Tufa or dead zone present (yes or no),
- Embankment slope condition, and
- Additional observation.

Among these items, the condition of the outlet opening was rated for percentage of blockage caused by coarse or fine materials accumulation. For instance, a drain outlet whose bottom semicircular area was blocked with debris or soil received a 50% outlet blockage rating. Any pavement distresses observed near inspected drainage spots were also recorded (pictures and videos).

### FINDINGS AND DISCUSSION

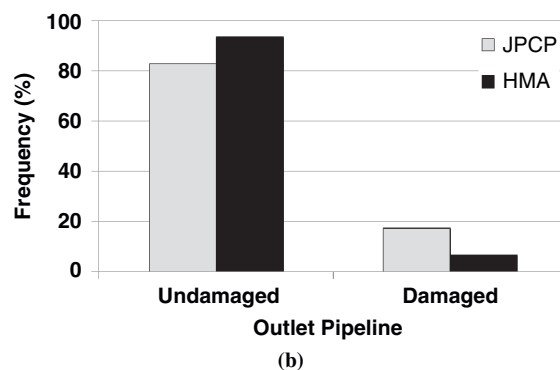
The findings and results from field investigations are discussed here with a primary focus on subdrainage outlet conditions and pavement distress assessment near subdrainage outlet locations.

#### Subsurface Drainage Outlet Conditions

Figure 1a illustrates a damaged subsurface drainage outlet pipeline among the ones that were investigated. A damaged condition was



(a)



(b)

FIGURE 1 Damaged subsurface drainage outlet pipe in investigated Iowa roadways: (a) I-35/S/MP 127.50 and (b) distribution of damaged and undamaged drainage outlet pipes.



reported during the field survey when an outlet pipe was broken or deformed. The forensic testing revealed that less than 20% of the investigated JPCP drainage outlet pipes were damaged, while less than 10% of HMA pavement drainage outlet pipes were damaged (see Figure 1*b*).

Typical drainage outlet conditions observed during field investigation include the following (see Figure 2): (a) no blockage (open), (b) tufa blockage, (c) sediment blockage, and (d) soil or aggregate blockage. No blockage was reported when the inside outlet pipe was in very clean condition. Tufa blockage was reported when there was buildup of calcium carbonate observed either inside the outlet pipe or near rodent guard screens. Tufa blockage was only observed in JPCP containing RPCC base materials. Sediment blockage was reported when dirty or debris materials were deposited inside the outlet pipe or nearby rodent guard screens. Soil blockage was reported when an end of the outlet was not exposed outside but covered by soil or aggregate.

Figure 3 presents distributions of four drainage outlet condition categories in the investigated Iowa roadway sections. About 35% of the investigated outlets in JPCPs and 60% of outlets in HMA pavements were not blocked by any materials. About 35% of outlets in JPCPs were blocked by tufa, about 17% were blocked by

sediment, and about 14% were blocked by soil deposits. However, most of the blocked outlets in HMA pavements were blocked by soil deposits. Only 2% of outlets in HMA pavements were blocked by sediment.

Figure 4*a* presents distributions of drainage outlet conditions with respect to JPCP base and subbase aggregate material types. Note that frequency values presented in Figure 4*a* were normalized according to each aggregate type rather than all aggregate types. As seen in this figure, tufa formation and drain outlet blockage were observed mainly in JPCP with RPCC subbase materials. Few drain outlets with tufa blockage were observed in JPCP with blended RPCC and virgin aggregate subbase materials.

Figure 4, *b* and *c*, presents blockage rates of drainage outlet conditions in JPCPs and HMA pavements, respectively. Note that frequency values in this figure were based on all outlet samples of each investigated pavement type. As seen in the figure, at higher blockage rates, JPCP drain outlets are blocked primarily by tufa rather than soil and sediment. However, irrespective of the blockage rate, the HMA pavement subdrainage outlets are blocked primarily by soil. Higher outlet blockage rates lead to slower discharge of water. However, higher blockage rates do not always stop the water from



(a)



(b)



(c)



(d)

FIGURE 2 Typical subsurface drainage outlet conditions in investigated Iowa roadways: (a) no blockage, I-35 south, Milepost 127.90; (b) tufa blockage, I-80 west, Milepost 56.72; (c) sediment blockage, IA-5 east, Milepost 86.50; and (d) soil blockage, IA-5 east, Milepost 140.35.

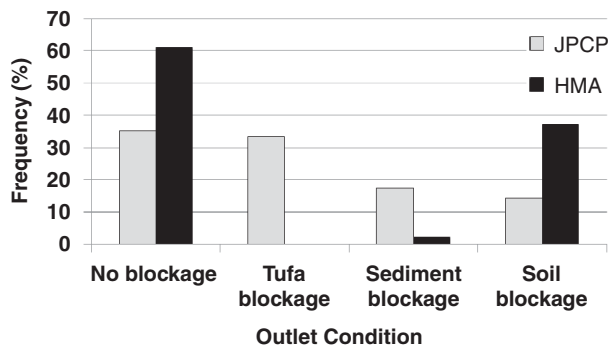


FIGURE 3 Distribution of Iowa roadway subsurface drainage outlet condition categories.

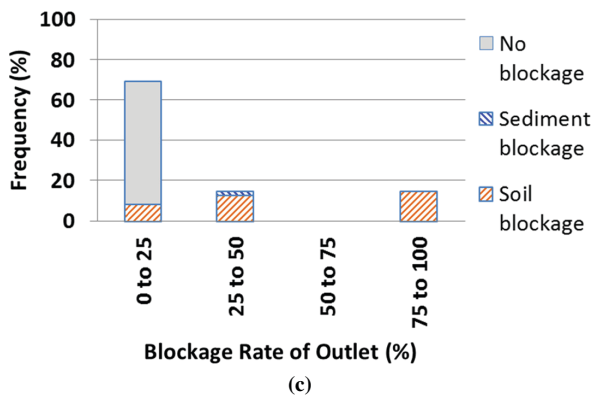
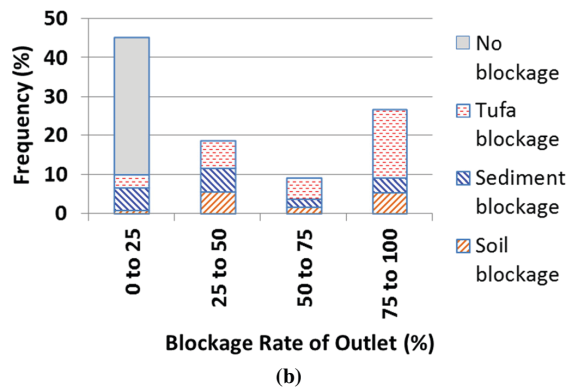
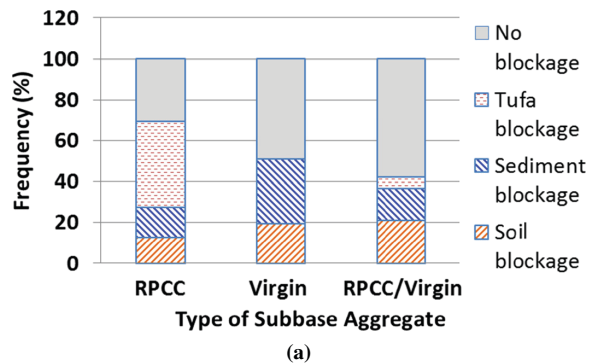


FIGURE 4 Subsurface drainage outlet condition distributions: (a) Iowa JPCP subbase aggregate type, (b) JPCP outlet blockage type and rate, and (c) HMA outlet blockage type and rate.

flowing from inside of the outlet pipe to outside of it, unless the outlet is completely blocked (i.e., 100% blockage rate).

Rodent guards have been used in Iowa pavements to keep mice, rats, and other small rodents from entering subdrains. The two types of rodent guards used in Iowa are mesh screen and fork-shaped ones. Only one drainage spot was observed as having rodent evidence during the field investigation in spite of the dry fall season. In light of the significant blockage caused by tufa or sediment in many of the investigated drain outlets, further complicated by the presence of rodent guards, the question of whether or not Iowa DOT should be using rodent guards has become a moot point. The mesh screen-type rodent guards in some drainage outlets, as shown in Figure 5, is causing clogging with tufa or sediment by filtering the flow of water. Removal of the rodent guards, as shown in Figure 5, often prevents this clogging problem.

### Pavement Distress Assessments Near Subsurface Drainage Outlets

Among the investigated sites, no pavement surface distress was observed on more than 90% of the spots (irrespective of the blockage rate) for both JPCP and HMA pavement types. It is important to note that the pavement sites included in the site selection were all constructed after 1990. The distress types observed in JPCP are transverse cracking, longitudinal cracking, and corner cracking. The only relevant distress observed for HMA pavement is transverse cracking.

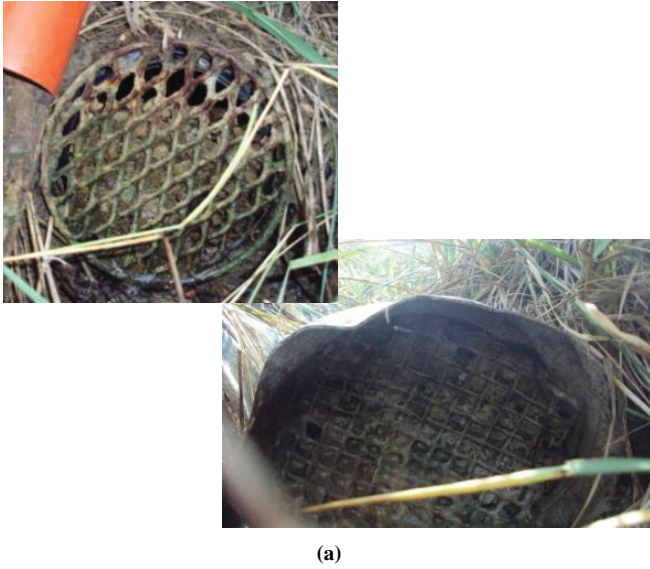
Contrary to engineering experience, most surface distresses were observed near open subsurface drainage outlet spots rather than blocked ones. The investigated JPCP sites with blocked outlet spots were constructed from 1990 to 2007 with PCC thicknesses ranging from 9 to 13 in. and AADTT ranging from 579 to 13,264. The JPCP sites with open outlet spots have similar ranges of pavement age, PCC thickness, and AADTT. The investigated HMA sites with both blocked and opened outlet spots were constructed from 1998 to 2006 with HMA thicknesses ranging from 9 to 15 in. and AADTT ranging from 738 to 1,730. No surface distresses were observed on blocked outlets in JPCP and little surface distress was observed on blocked outlets in HMA. Only one blocked outlet spot in HMA had transverse cracking. On the contrary, transverse cracking was observed on pavement surfaces near open subsurface drainage outlet spots for both pavement types. Transverse cracking was observed near several culverts rather than drainage outlet spots. On the basis of the limited data (especially with respect to pavement age) collected during this study under unusually dry precipitation conditions, no significant conclusion could be drawn about the effect of drainage outlet conditions on the development of moisture-related pavement distresses.

Rather than surface distresses, more shoulder distresses (shoulder drop or cracking), as shown in Figure 6, were observed near blocked or damaged drainage outlet spots. The frequency of outlet spots with observed shoulder distress under opened and blocked outlet conditions was compared. It was found that more than 10% of the blocked drainage outlet spots have shoulder distresses, while only 2% among opened drainage outlets have shoulder distresses.

### CONCLUSIONS AND RECOMMENDATIONS

The goal of this research study was not to investigate whether Iowa pavements need subdrains or not, but rather to conduct an extensive performance review of primary interstate pavement subdrains in





(a)



(b)

FIGURE 5 Subsurface drainage outlet conditions: (a) with mesh screen guard, I-29 north, Milepost 64.45 (top) and I-80 west, Milepost 56.72 (bottom) and (b) without mesh screen guard, I-80 west, Milepost 103.95.



(a)



(b)



(c)



(d)

FIGURE 6 Observations near Iowa JPCP blocked drainage outlet, at I-80 west, Milepost 48.30 (left) and at I-29 north, Milepost 70.84 (right): (a and b) shoulder dropping and cracking, (c) blocked outlets, and (d) blocked outlets and damaged outlets.



Iowa and to determine the cause of the problem if there are drains that are not functioning properly. The major conclusions drawn from the study, which included an extensive literature review as well as field investigation, are as follows:

- Most Iowa subsurface drainage system outlet blockage is caused by tufa, sediment, and soil.
- More than 80% of drainage outlets in JPCP were not damaged, while less than 20% were damaged. For HMA pavements, less than 10% of drainage outlets were broken.
- About 35% of outlets in JPCP and 60% of outlets in HMA pavements were not blocked by any materials. About 35% of outlets in JPCP were blocked by tufa, about 17% were blocked by sediment, and about 14% were blocked by soil deposits. However, most of the blocked outlets in HMA pavements were blocked by soil deposits. Only 2% of outlets in HMA pavements were blocked by sediment.
- Higher blockage rates reduce the flow rate of water inside outlet pipes. However, higher blockage rates do not always stop water flowing from inside the outlet pipe to outside the outlet pipe unless the outlet is completely blocked (100% blockage).
- The use of gate or mesh screen-type rodent guards has the potential to cause outlet blockage. Considering that very little rodent evidence was observed in Iowa subdrainage outlets during field investigations, it is highly recommended that these rodent guards be removed from existing outlets and not be used to cover the newly installed drainage outlets in Iowa in the future.
- The use of RPCC as a subbase material results in tufa formation, which is the primary cause of drainage outlet blockage in JPCP. However, those JPCP spots that utilized blended RPCC and virgin aggregate materials as subbase materials experienced fewer outlet blockages from tufa formation.
- On the basis of the limited data (especially with respect to pavement age) collected during this study under unusually dry precipitation conditions, no significant conclusion could be drawn regarding the effect of drainage outlet conditions on development of moisture-related pavement distresses.
- Little or no pavement surface distresses observed at blocked outlet sites does not lead to the conclusion that Iowa pavements do not need any subdrains or subdrain outlet maintenance. This study investigated only those pavement sites with a subdrain system. The presence of a subdrain system alone is sufficient for water to somehow find its way out of the pavement system unless the outlet is completely blocked. Note that pavement failures in Iowa have been reported on roadways without any subdrain system.
- Shoulder distresses (shoulder drop or cracking) were observed near blocked drainage outlet spots. Among blocked drainage outlet spots, more than 10% have shoulder distresses, while, among opened drainage outlet spots, only 2% have shoulder distresses.
- It is expected that the use of a drain outlet protection mechanism, such as a splash pad mechanism used in nearby states, will be highly helpful in protecting and improving the performance of Iowa subdrains.

On the basis of these findings and recommendations, an expanded follow-up research study was recently initiated by the Iowa DOT to evaluate the seasonal variation effects (dry fall versus wet spring, summer, etc.) on subdrain outlet condition and performance; investigate the condition of composite pavement subdrain outlets (which was not included in this current study since most composite pavements in Iowa were constructed before 1990); examine the effect of resurfacing, widening, and rehabilitation on subdrain outlets; and

investigate the characteristics of tufa formation in Iowa subdrain outlets.

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## REFERENCES

1. Chapter 6, Geotechnical: 6G, Subsurface Drainage Systems. In *State-wide Urban Design and Specifications*. Institute for Transportation, Iowa State University, Ames, 2010.
2. Hassan, H.F., T.D. White, R. McDaniel, and D. Andrews. Indiana Subdrainage Experience and Application. In *Transportation Research Record 1519*, TRB, National Research Council, Washington, D.C., 1996, pp. 41–50.
3. Christopher, B. R. *NCHRP Synthesis of Highway Practice 285: Maintenance of Highway Edgedrains*. TRB, National Research Council, Washington, D.C., 2000.
4. Hall, K. T., and C. E. Correa. *NCHRP Report 499: Effects of Subsurface Drainage on Performance of Asphalt and Concrete Pavements*. Transportation Research Board of the National Academies, Washington, D.C., 2003.
5. ARA, Inc., ERES Consultants Division. *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*. Final report, NCHRP Project 1-37A. Transportation Research Board of the National Academies, Washington, D.C., 2004. <http://www.trb.org/mepdg/guide.htm>.
6. Hall, K. T., and J. A. Croveti. *NCHRP Report 583: Effects of Subsurface Drainage on Pavement Performance: Analysis of the SPS-1 and SPS-2 Field Sections*. Transportation Research Board of the National Academies, Washington, D.C., 2007.
7. Steffes, R. *Laboratory Study of the Leachate from Crushed Portland Cement Concrete Base Material*. Materials Laboratory Research Project. Final Report MLR-96-4. Iowa Department of Transportation, Ames, 1999.
8. Ceylan, H., K. Gopalakrishnan, S. Kim, and R. F. Steffes. *Evaluating Roadway Subsurface Drainage Practices*. Project Report 12-428. Institute for Transportation, Iowa State University, Ames, 2013.
9. Hall, K. T. *NCHRP Research Results Digest 268: Performance of Pavement Subsurface Drainage*. Transportation Research Board of the National Academies, Washington, D.C., 2002.
10. Zubair, A., T. D. White, and P. L. Bourdeau. *Pavement Drainage and Pavement Shoulder Joint Evaluation and Rehabilitation*. Draft Final Report FHWA/IN/JHRP-93/2. FHWA, U.S. Department of Transportation, 1993.
11. Espinoza, R. D. *Numerical Analysis of Unsaturated Flow in Porous Media*. PhD dissertation. Purdue University, West Lafayette, Ind., 1999.
12. Canelon, D. J., and J. L. Nieber. *Evaluating Roadway Subsurface Drainage Practices*. Report MN/RC 2009-08. Minnesota Department of Transportation Research Services Section, Saint Paul, 2009.
13. Arika, C. N., D. J. Canelon, and J. L. Nieber. *Subsurface Drainage Manual for Pavements in Minnesota*. Final Report MN/RC 2009-17. University of Minnesota, Minneapolis, 2009.
14. Bhattacharya, B. B., M. P. Zola, S. Rao, K. Smith, and C. Hannebian. *Performance of Edge Drains in Concrete Pavements in California*.



- Proc., National Conference on Preservation, Repair, and Rehabilitation of Concrete Pavements*, Saint Louis, Mo., 2009, pp. 145–158.
15. Stroup-Gardiner, M., and T. Wattenberg-Komas. *NCHRP Synthesis of Highway Practice 435: Recycled Materials and Byproducts in Highway Applications—Summary Report*, Vol. 1. Transportation Research Board of the National Academies, Washington, D.C., 2013.
  16. Snyder, M.B., and J.E. Bruinsma. Review of Studies Concerning Effects of Unbound Crushed Concrete Bases on PCC Pavement Drainage. In *Transportation Research Record 1519*, TRB, National Research Council, Washington, D.C., 1996, pp. 51–58.
  17. White, D.J., H. Ceylan, C.T. Jähren, T.H. Phan, S. Kim, K. Gopalakrishnan, and M.T. Suleiman. *Performance Evaluation of Concrete Pavement Granular Subbase—Pavement Surface Condition Evaluation*. Final Report for IHRB Project TR-554. CTRE, Iowa State University, Ames, 2008.
  18. Phan, T.H. *Laboratory and Field Investigations of Recycled Portland Cement Concrete Subbase Aggregates*. PhD dissertation. Iowa State University, Ames, 2010.
  19. Gupta, J.D., and W.A. Kneller. *Precipitate Potential of Highway Subbase Aggregates*. Final Report FHWA/OH-94/004. University of Toledo, Toledo, Ohio, 1993.
  20. Narita, K., T. Onoye, and Z. Takata. On the Weathering Mechanism of LD Converter Slag. *Iron and Steel*, Vol. 64, No. 10, 1978, pp. 68–77.
  21. Gupta, J.D., and D. Dollimore. *Magnitude Assessment of Free Lime and Hydrated Limes Present in RPCC Aggregates*. Final Report FHWA/OH-2002/014. University of Toledo, Toledo, Ohio, 2002.
  22. Bruinsma, J.E., K.R. Peterson, and M.B. Snyder. Chemical Approach to Formation of Calcite Precipitate from Recycled Concrete Aggregate Base Layers. In *Transportation Research Record 1577*, TRB, National Research Council, Washington, D.C., 1997, pp. 10–17.
  23. Iowa Department of Transportation, Division 21. *Earthwork, Subgrades, and Subbases in Standard Specifications with GS-12003*. <http://www.iowadot.gov/erl/current/GS/Navigation/nav21.htm>. Accessed Oct. 9, 2013.

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